DALHOUSIE UNIVERSITY
FACULTY OF ENGINEERING

Mitchell Mills, Johnathan Slaunwhite, Brett McLellan, Jarod Fougere

enginuity

Department of Electrical Engineering

Wireless Soil Monitoring System for Vertical Farming

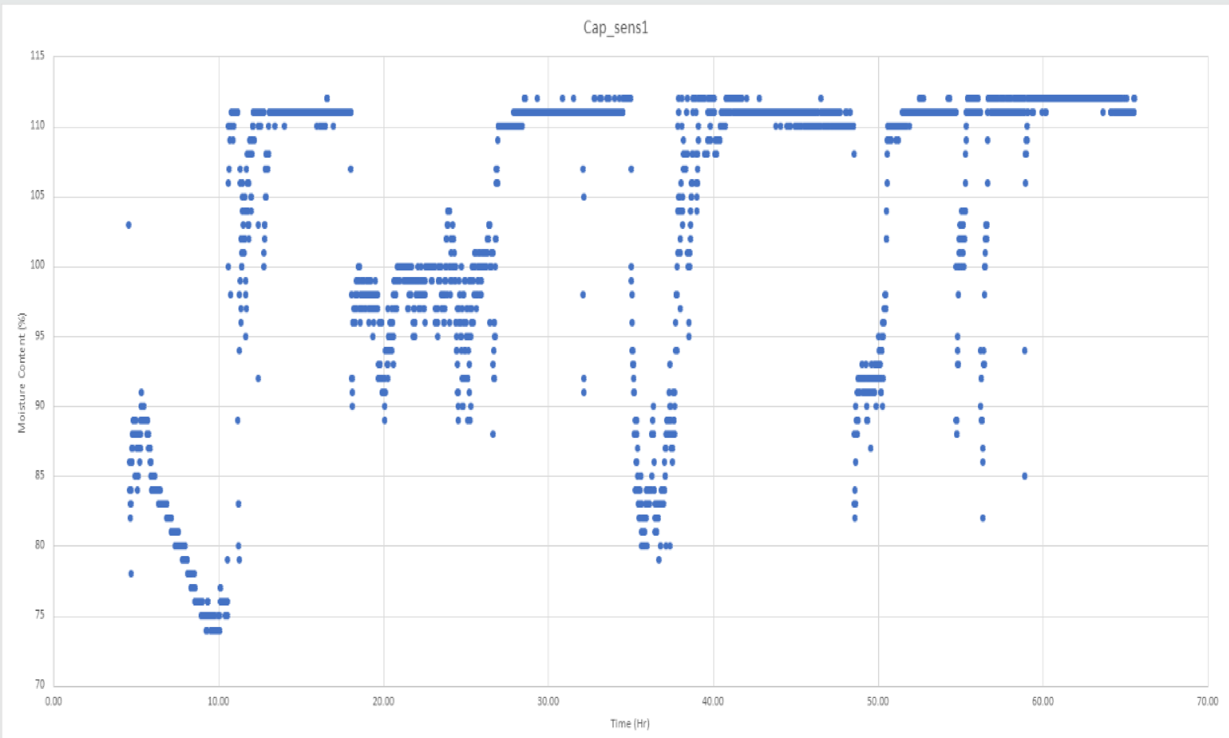
Introduction

- Enginuity has developed a remote monitoring and control system for controlled growing environments called iFarm.
- Using external sensors, the iFarm currently has the capability to accurately measure humidity, temperature, electrical conductivity (EC), total dissolved solids (TDS), and pH.
- Due to the different variables such as different dielectric constants and compaction between soil mediums, Enginuity has been unable to find a low-cost option to accurately measure soil moisture.
- Our goal is to design and fabricate a low-cost soil moisture sensor that will give accurate results and can be integrated with Enginuity's existing iFarm system

Research & Testing

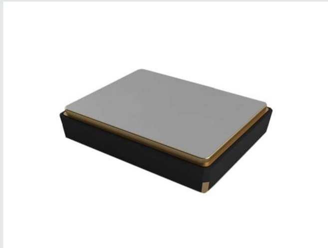
- There are four common techniques for measuring soil moisture levels:
  - Resistive
  - Capacitive
  - Time Domain Reflectometry (TDR)
  - Frequency Domain Reflectometry (FDR)

- We measured the different sensor types in different orientations by running a two-minute flood every six hours.
- During our testing, we found that the capacitive sensor was the best mix of cost and performance. We also found that the sensors performed much better when they were oriented in a vertical position.

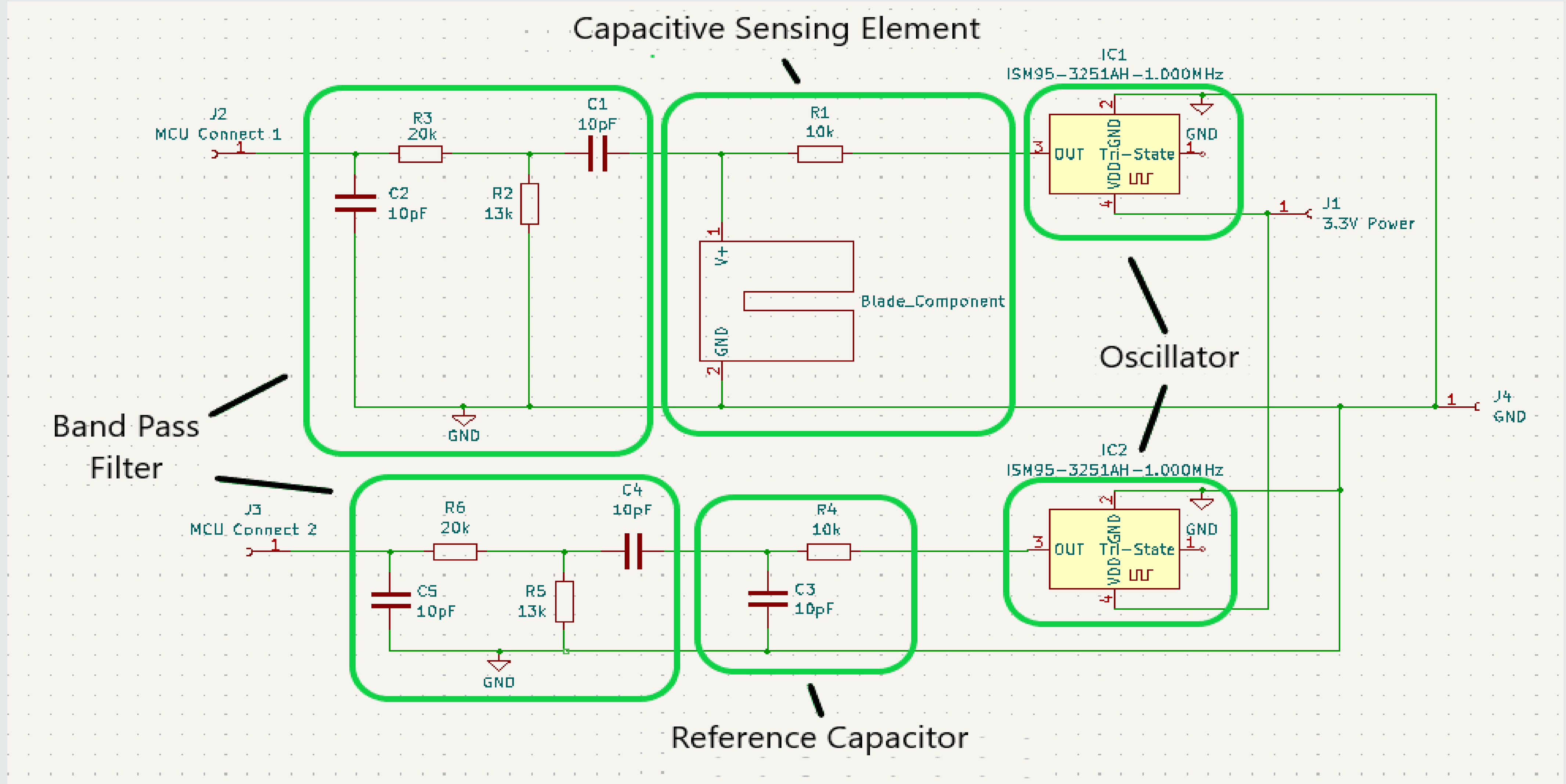


Circuit Design

- Our sensor design has four main components:
- A microcontroller is used to collect the data from the system. For ease of testing, we used the *Arduino MEGA-2560*. However, if the sensor was to be built on a larger scale, we would recommend using the *ARM Cortex M0+.*
- A crystal oscillator is used to send a frequency through to the capacitive probes. We have decided to use the ISM95 oscillator to provide an output frequency of 1MHz.

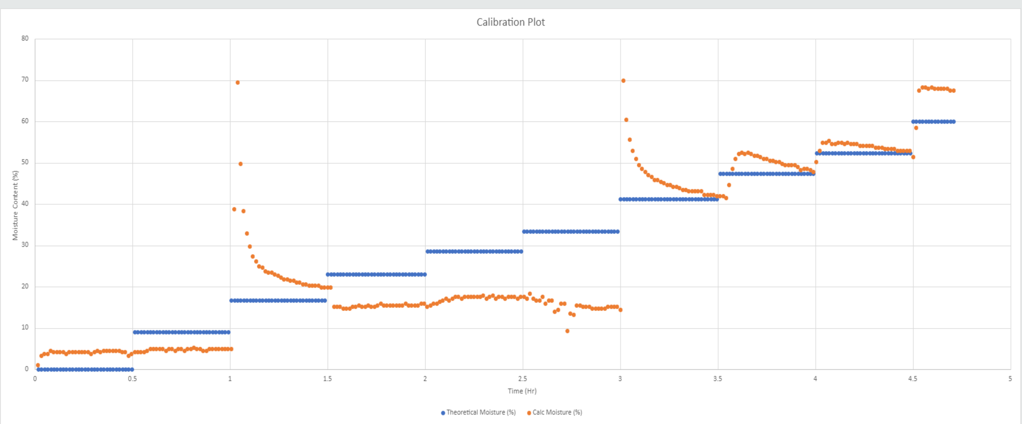


- The capacitive sensing element is implemented as a RC filter, with the probes of the sensor being used as the capacitor. This will allow us to relate the rise time of the voltage to the amount of moisture in the soil.
- A band-pass filter is used to isolate the output frequency. We are using a second order filter with a center frequency of 1MHz and a bandwidth of 400kHz.



Calibration

- Each growing medium retains water differently
- The calibration process has four steps:
  - Dry growing medium using oven or dehumidifier to remove all moisture
  - Poll sensor in a measured dry sample
  - Create solution of a known moisture percentage by adding water using this formula
  - Poll sensor in wet sample

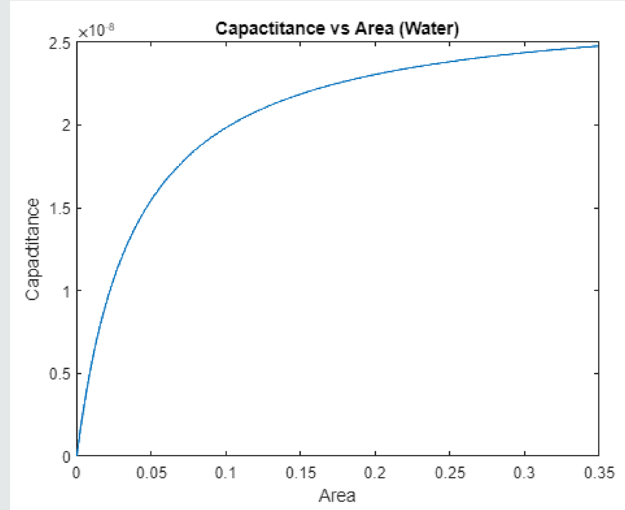


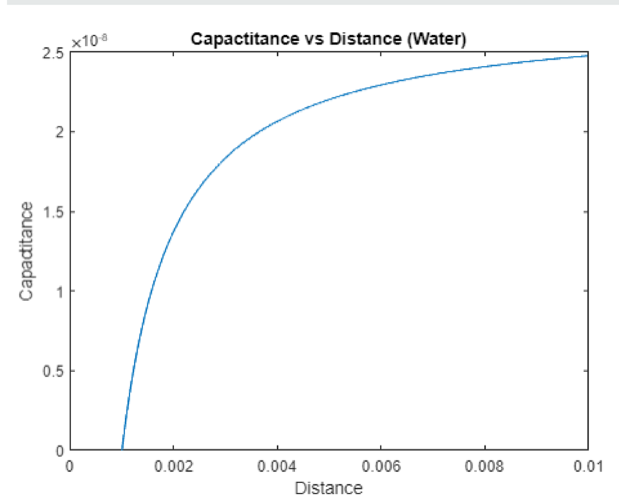
$$mass_{water} = \frac{mass_{medium} \times moisture\,\%}{100 - moisture\,\%}$$

- Software uses these points to create linear conversion between voltage output and moisture content.

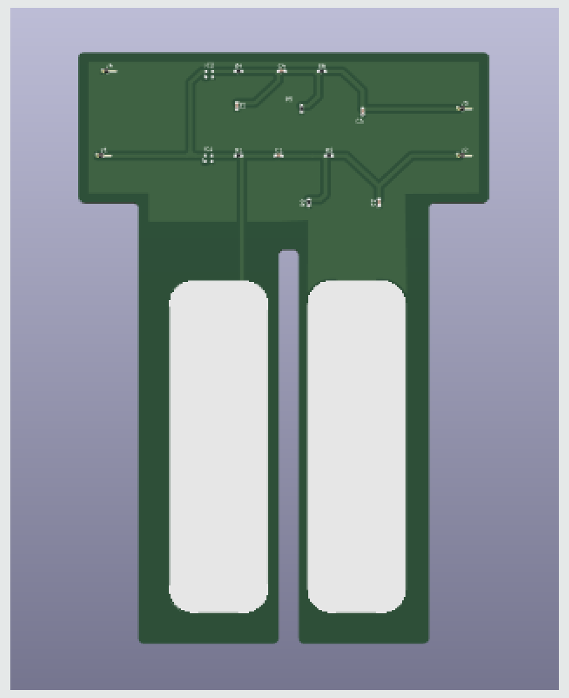
Probe Design

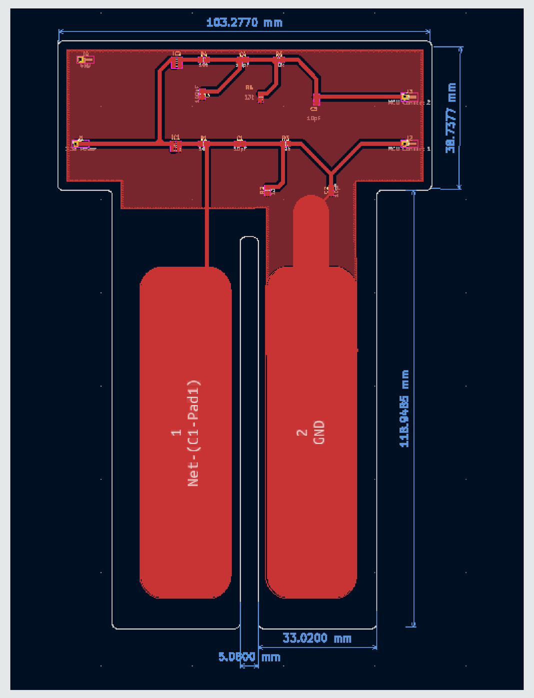
- The figures below show the change in capacitance for different probe areas and distances.





- Dimensions needed to be picked on a portion of the graph that is relatively flat to obtain a more stable reading.
- Chosen dimensions were an area of 0.225 cubic meters (9cm x 2.5cm) and a distance of 6mm.





Conclusion

- The proposed product can measure the moisture content of different soil mediums, gives accurate results and is easily integrated with Enginuity's existing platform
- Calibration for the sensor functions by using the linear relation between dielectric permeability, moisture percentage and capacitance/frequency

$$C = \frac{\varepsilon A}{d}, \quad \varepsilon \propto C, \; C \propto F \;\; \rightarrow \therefore \varepsilon \propto F$$

- The calibration process obtains two points on this line, allowing for the equation to be extrapolated

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